Shear-Banding in Colloidal Systems

J. Dhont
Forschungszentrum Juelich
IFF, Weiche Materie
D-52425 Juelich, Germany

When the shear-stress decreases with increasing shear-rates, the usual linear velocity profile in a two-plate geometry becomes unstable. The stable stationary state is now a state where two regions (the "bands") with different shear rates coexist. Within these bands the shear rate is a constant, independent of position. In the small region (the "interface") which connects the two bands, the shear-rate changes very rapidly with position. These spatial gradients in shear-rate are so large, that the standard constitutive relation (stress=shear-rate x shear-viscosity) is insufficient to describe the interface. It is shown how to extend the standard constitutive expression for the stress in order to be able to describe shear-banding. The shear-banding instability turns out to be mathematically very similar to the spinodal Cahn-Hilliard instability. In particular, in the initial stage of shear-banding, there is one particular Fourier component which grows most rapidly and dominates the flow pattern after some time. Furthermore, in case of a controlled shear-rate experiment, a "modified Maxwell equal area construction" can be derived to obtain the shear-rates in the bands and their common stress. The microscopic origin of the shear-banding transition for a suspension of rigid, rod-like colloids/polymers is discussed, and a microscopic derivation of the constitutive relation is presented.